RISK PREMIA IN FUTURES MARKETS: PRICE VOLATILITY, TIME-VARYING RISK PREMIA, AND RETURNS TO SPECULATORS.

BY

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I dedicate this dissertation to my parents.

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This dissertation consists of three related essays on risk premia in futures markets. The first essay tests the existence of risk premia in futures markets. The tests are based on the returns to professional (or large) hedgers and speculators calculated from data on commodity futures prices and foreign currency futures prices, as well on traders' commitments on the futures trading. The empirical test results show that professional hedgers consistently lose money on the average, implying that they pay risk premia for the futures contracts. It is also found that the

professional speculators consistently make profits on the average in the futures markets, attributable to risk-bearing rather than superior information.

The second essay examines the effect of the futures price volatility on the risk premium hedgers pay for the futures contract, since it has been argued that the more uncertain the futures price is the more risk premium hedgers pay. The model is tested by regressing the ex post risk premium the professional hedgers pay for the futures contract on the ex post variance of the futures price. Estimation of the model using the seemingly unrelated regression method indicates that there is a significantly positive relationship between the volatility of the futures price and the risk premium hedgers pay for every futures contract investigated.

Finally, the study examines whether the professional speculators receive time-varying risk premia in the framework of the Generalized Autoregressive Conditional Hetroskedasticity in Mean (GARCH-M) model. The return from holding the futures contract is regressed on the conditional variance of the return. The GARCH model fits well for every regression equation. The test results show that the professional speculators are risk averse and receive significant time-varying risk premia from holding the futures contracts.

CHAPTER 1
INTRODUCTION

Futures trading enables hedgers to transfer risks of uncertain price changes to others who are willing to assume them. Do hedgers compensate those who bear the risks? To what extent do hedger pay a risk premium to speculators for the transfer of risks? What determines the magnitude of the risk premium? These questions have been of interest to policy makers as well as researchers. The purpose of dissertation is, therefore, to provide empirical evidence as to these questions.

The question whether or not hedgers pay a risk premium to speculators for the return of risk-bearing of a futures contract has been extensively studied by several researchers. The empirical evidence depends on which assumption the researcher makes. Studies which assume that hedgers as a whole are net short in futures markets show that there is no risk premium that hedgers pay to speculators. These include the studies of Telser [1958] and Dusak [1973]. On the other hand, studies which assume that hedgers are net short or net long generally indicate that hedgers pay a risk premium to speculators as a compensation

for risk-sharing. These include the studies of Houthakker [1957], Rockwell [1967], and Chang [1985], who have utilized the data on traders' commitments.

In chapter 2 of this dissertation, adopting the approach of the latter studies, we estimate the returns to large hedgers as a whole and large speculators as a whole to test whether hedgers pay a risk premium to speculators as a compensation for risk-bearing. The estimated returns to large hedgers and large speculators will be utilized as the data for the tests of chapters 3 and 4.

The objective of chapter 3 is to test the effect of volatility of futures prices on the risk premium hedgers pay for a certain futures contract. It has been argued that the more uncertain the price of a futures contract, the more premium hedgers pay. The uncertainty of the futures price is measured by it variance. So this hypothesis is tested by regressing the ex post risk premium the large hedgers pay for a certain futures contract on the ex post variance of the futures price. It is also tested that whether or not there is any relationship between the risk premium hedgers pay for a certain futures contract and the volatility of other futures prices. For the estimation of the regression equations, we use seemingly unrelated regression procedures.

The objective of chapter 4 is to test whether the risk premia large speculators receive from holding futures contracts are time varying. The Autoregresive Conditional

Heteroskedasticity (ARCH) model developed by Engle [1982] enables one to analyze the time varying risk premia. Since the Generalized ARCH process describes the data better, we use the GARCH-M model.

Finally, chapter 5 concludes and summarizes the results of this dissertation with a discussion of policy implication.

CHAPTER 2
EXISTENCE OF RISK PREMIUM

Introduction

One of the major economic functions of futures markets is a risk-sharing role.[1] Firms hedge their planned sales of products by selling futures contracts or hedge their purchases of inputs by buying futures contracts. Besides hedgers, there are speculators in the futures markets who seek profits from price changes. If speculators are risk-averse as a whole in the futures markets, hedgers must pay a risk premium to speculators as a compensation for the risk-sharing in the futures markets. This theory was developed by Keynes [1930] and Hicks [1946]. They argued that the futures price for a storable commodity should normally be slightly below the expected future spot price in order to induce speculators to assume some risk. The difference between the futures price and the expected future spot price is a risk

[1] Another major economic function of futures market is a price discovery role. Futures price for a commodity represents all the information about the future cash price. So economic agents make plans and decisions by looking at the futures price.

premium which they called "normal backwardation." The theory is based upon the assumption that hedgers as a whole are net short.

Early studies on risk premia in commodity futures markets adopt Keynes' and Hicks' original assumption that hedgers as a whole are net short. So they view the risk premium as returns to speculators who continuously hold net long positions. These include the studies of Telser [1958] and Dusak [1973]. Telser argues that since the expected future spot price of a commodity is higher than the price of a futures contract according to the theory of Keynes and Hicks, the futures price should show an upward trend as the maturity date came. He finds that futures prices show no trend in wheat and cotton markets. He thus concludes that hedgers can reduce their risks without paying compensation to speculators. Dusak examines the existence of risk premia in wheat, corn and soybeans futures markets within the context of the capital asset pricing model (CAPM). She finds that the systematic risks of the three commodity futures examined are not significantly different from zero.

The assumption that speculators continuously hold net long positions has been relaxed by several researchers, who argue that speculators can obtain risk premia in the futures markets even if futures prices do not show a trend. According to the theory of hedging pressure, Cootner [1960a] presented several cases in support of the contention that

risk premia can exist in the commodity futures markets. He shows that it is possible for speculators to profit by being long after the peak of net short hedging and by being short after the peak of net long hedging. Also, Carter, Rausser, and Schmitz [1983] (CRS) respecify Dusak's study by taking into account that speculators can be either net short or net long. Assuming that risk parameters are stochastic and a function of speculators' actual net position, they find that estimates of systematic risks are not zero.

The availability of data on traders' commitments has enabled researchers to allocate a risk premium in futures markets between speculators as a whole and hedgers as a whole. It was Houthakker [1957] who first utilized the data on traders' commitments to estimate the profits of speculators and hedgers. Although he does not perform an explicit test of whether there exist risk premia in the futures markets, his study indicates that speculators obtain risk premia in return for their risk-bearing.

After Houthakker's study, researchers have tried to decompose speculators' profits into risk premia and profits due to forecasting ability. Rockwell [1967] distinguishes speculators' rewards for risk-bearing from those of forecasting ability. He defines risk premium as the return earned by a hypothetical speculator who follows a naive strategy of being long when hedgers as a whole are net short and short when hedgers are net long. He finds that the rate

of the risk premium is 2.3% per year on the average for all markets and that the risk premium is negative for 11 out of 25 markets. One problem with Rockwell's study is that he might have underestimated the risk premium to the hypothetical speculator. He estimates the returns on risk-bearings as profits of all traders(large speculators, large hedgers, and nonreporting small traders) on long positions when hedgers are net short minus those on long positions when hedgers are net long. He ignores that hedgers have a constraint on hedging while speculators do not have any constraint.

Employing nonparametric statistical methods Chang [1985] examines the existence of positive profits to speculators in wheat, corn, and soybean futures markets. He finds that there was a reward to a hypothetical speculator defined by Rockwell for risk-bearing. He also tests whether or not large speculators' profits are combined rewards for both risk-bearing and superior forecasting ability. He finds that the large speculators were rewarded for both risk-bearing and forecasting ability in wheat futures market while they are rewarded for only risk-bearing in corn and soybean futures markets. His study is only to test whether or not the large speculators receive risk premia for their risk-bearing and they get rewards for their forecasting ability. He does not estimate the magnitudes of the risk premia and rewards for forecasting ability.

In this paper we attempt to measure the magnitudes of the risk premia which are allocated between hedgers and speculators. Like previous studies, the limitation of the data of traders' commitments forces us to consider only large hedgers and large speculators. The returns to large hedgers and large speculators are calculated by utilizing the data of traders' commitments and monthly futures prices.

Data

For this study a sample of futures contracts of six commodities has been collected: wheat, corn, oats, soybeans, soybeans oil, and soybeans meal futures which are traded in the Chicago Board of Trade (CBOT), and futures contracts of five foreign currencies: Canadian dollar, British pound, Deutsche mark, Japanese yen, and Swiss franc futures, which are traded in the International Monetary Markets (IMM) of the Chicago Mercantile Exchange (CME). There are five different contracts depending on delivery month per year for six commodities and four for five foreign currencies. Thus, the sample of thirty futures contracts for the six commodities and twenty futures contracts for the five foreign currencies will be analyzed.

Data on futures prices for six commodities have been collected from the Chicago Board of Trade Commodity Data Tape. For the thirty commodity futures contracts, closing

price quotations have been used. Data on futures prices for the five foreign currencies have been collected from the Data Tape provided by the Center for the Study of Futures Markets at Columbia University. For the twenty futures contracts of foreign currencies, settlement price quotations have been used.

Traders' market positions of being long or short are available from *Commitments of Traders in Commodity Futures* published by the Commodity Futures Trading Commission (CFTC).[2] This publication reports traders' commitments over time, which are divided into three groups: (large) hedging, (large) speculative, and nonreporting. Traders whose commitments in any one futures contract exceed the reporting limit are required to report their entire position to the Commodity Futures Trading Commission, which classify futures commitments as either hedging or speculative. The above publication reports traders' commitments which are classified according to a commodity, not a delivery month within a commodity. For instance, traders' commitments on wheat futures, not on March wheat futures, are classified into large hedging, large speculative, and nonreporting.

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[2] The Commodity Futures Trading Commission was established as an independent agency by the Commodity Futures Trading Commission Act of 1974 (88 stat. 1989; U.S.C. 41), superseding the Commodity Exchange Authority of the Department of Agriculture, which was abolished by the same act.

Thus we can obtain the data of whether large speculators and large hedgers are net long or net short in each monthly period on each commodity futures. But we need traders' commitments on a delivery month within the commodity futures. To solve this problem we assume that all delivery months within a commodity futures have the same percentage of open interest.[3] Hence we can use the data of traders' net position on a commodity for every contract month of a commodity.

For the commodity futures, the sample periods are from January 1976 through December 1984 excluding the year of 1982. For the foreign currency futures, the sample periods are from January 1977 through September 1988 excluding the year of 1982. The year of 1982 is excluded from the sample because the CFTC discontinued the reports of traders' commitments in the year of 1982.

Since the data on large hedgers' (speculators') net positions in a futures delivery month within a commodity and the data on prices of this futures contract are obtained, the rate of return to large hedgers (speculators) as a whole

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[3] This assumption is identical to the assumption made by Chang(1985). Houthakker(1957) and Rockwell made a similar assumption. In their studies, traders' commitments on a commodity futures were classified according to trading groups and delivery months. So they assumed that the distribution of total open interest according to trading groups and according to delivery months is statistically independent, in order to obtain traders commitments on each delivery month within a commodity futures.

for month t is calculated as follows.

$\pi_t = (p_{h,t} - p_{h,t-1})/p_{h,t-1}$ if large hedgers (speculators) as a whole are net long.

$\pi_t = (p_{h,t-1} - p_{h,t})/p_{h,t-1}$ if large hedgers (speculators) as a whole are net short.

where $P_{h,t}$ is the price of a futures contract at the end of month t, which matures at time h. The results of this study are interpreted as those of large speculators as a whole and large hedgers as a whole.[4] These are also interpreted as those of a representative large speculator (hedger) who follows a simple strategy of being long when large speculators (large hedgers) as a group are net long and short when they are net short.

The Hypotheses

The first hypothesis to be tested is whether or not the representative large hedger consistently loses money in the futures markets. It is to test whether or not the representative large hedger's average profit is significantly negative in the markets. The null hypothesis states that the representative large hedger is not a consistent loser in the futures markets. It is tested

[4] The market shares of large hedgers, large speculators, and small traders are about 40% to 60%, 10% to 20%, and 30% to 40% on the average, respectively.

against the alternative hypothesis that he consistently loses in the markets. The rejection of the null hypothesis supports the idea that large hedgers pay some risk premium.

The second hypothesis to be tested is whether the representative large speculator consistently makes profit in the futures markets. It is to test whether or not the representative large speculator's average profit is significantly positive in the markets. The null hypothesis is that the representative large speculator is not making money on the average in the futures markets. It is tested against the alternative hypothesis that he is making a profit on the average in the markets. The rejection of the null hypothesis would indicate that the representative large speculator makes profit either by bearing risk or by superior information. The first hypothesis and the second hypothesis are not identical because there are also small traders (hedgers and speculators) in the futures markets.

The third test is to test whether the representative large speculator makes a profit by a simple strategy of being in the opposite position of the representative large hedger or by a better strategy. For this test, it is convenient to adopt the hypothetical speculator who follows a simple strategy of being long when large hedgers are net short and short when large hedgers are net long as Rockwell defines. So we test whether or not the representative large speculator makes more than the profit which the hypothetical

speculator makes. The excess of the representative large speculator's profit over the hypothetical speculator's profit on the average implies that representative large speculator is using a better strategy than the simple. It indicates that large speculators earn additional profits at the expense of small traders since large speculators have better information than small traders. For instance, consider a situation when large hedgers are net short and large speculators have information that price will be down ,but small traders don't have. In this case the large speculators will take net short position.

Based on a sample of the representative large hedger's profits $\pi^h_1 \ldots \pi^h_t$, hypothesis to be tested is

$H_0 : \mu = \mu_0$ against

$H_a : \mu < \mu_0$

where μ is the true mean of the representative large hedger's profit and $\mu_0 = 0$. Since the sample mean $\bar{\pi}^h$ has an approximately normal distribution for large sample, the test statistic is

$$z^h = \frac{\bar{\pi}^h - \mu_0}{\sigma_{\bar{\pi}}} = \frac{\bar{\pi}^h - \mu_0}{s/n^{1/2}}$$

where s^2 is the sample variance, and n is the number of observation. With a significance level of α, the null hypothesis is rejected if $z^h < -z^h_\alpha$

For the representative large speculator, the hypothesis to be tested based on a sample of $\pi^s_1 \ldots \pi^s_t$ is

$H_0 : \theta = \theta_0$ against

$H_a : \theta > \theta_0$

where θ is the true mean of the representative large speculator' profit and $\theta_0 = 0$. The test statistic is

$$z^s = \frac{\bar{\pi}^s - \theta_0}{\sigma_{\bar{\pi}}} = \frac{\bar{\pi}^s - \theta_0}{\delta^2/m^{1/2}}$$

where δ^2 is the sample variance, and m is the number of observations. With a significance level of α, the null hypothesis is rejected if $z^s > z^s_\alpha$

The third hypothesis is tested based upon a sample of the representative large speculator's profits $\pi^s_1 \ldots \pi^s_t$ and the hypothetical speculator's profits $w^s_1 \ldots w^s_t$. The hypothesis to be tested is

$H_0 : \theta = v$ against

$H_a : \theta > v$

where θ and v are the true means of the representative large speculator's profit and the hypothetical speculator's profit, respectively.

For large samples the test statistic is

$$z = \frac{\bar{\pi}^s - \bar{w}^s - D_0}{\sigma_{\pi w}}$$

where $\sigma_{\pi w} = (s^2/n+\delta^2/m)^{1/2}$ and $D_0 = \theta - v = 0$. With a significance level of α, the null hypothesis is rejected if $z > z_\alpha$

Empirical Results

The results of tests for the representative large hedger and speculator are reported in Tables 2-1 through 2-22. The null hypothesis that the representative large hedger does not consistently lose in the futures markets can be rejected for most of the futures contracts examined in this study. The representative large hedger's average profit is significantly negative for most of these futures contracts. The significance level is lower for oats and soybeans meal futures while it is higher for foreign currency futures. The results support the evidence that the representative large hedger is consistently losing money in the futures markets. This indicates that large hedgers pay some risk premium in the futures markets.

The null hypothesis that the representative large speculator is not a consistent winner in the futures markets is rejected for every futures contracts examined here. The representative large speculator's average profit is significantly positive for every futures contracts. That is, the representative large speculator consistently makes profit on the average in the futures markets. This evidence furnishes an explanation on why large speculators continue to remain in the futures markets. The above findings are consistent with Chang's [1985], even though his study is limited to only wheat, corn, and soybeans futures.

This study provides us with the magnitudes of the profits of the representative large hedger and speculator which Chang doesn't consider. The representative large speculator's average profits are higher than the representative large hedger's average losses in all commodity futures markets except the corn futures market. It is noticeable that the representative large speculator' average profits in wheat futures market are twice as high as the representative large hedger's average losses in these markets. In the wheat futures market, the average rates of the representative large speculator's profits are from 3.33% to 3.82% per month while the average rates of the representative large hedger's losses are from 0.87% to 1.51% per month. In contrast, in the corn futures market the average rates of the representative large speculator's profits are almost equal to the average rates of the representative large hedger's losses in this market. In the corn futures market the average rates of the representative large speculator's profits are from 1.90% to 2.18% per month and the average rates of the representative large hedger's losses are from 1.75% to 2.02% per month. In the other commodity futures markets (oats, soybeans, soybeans meal, and soybeans oil), the average rates of the representative large speculator's profits are from 1.81% to 3.21% per month and the average rates of the representative large hedger's losses are from 0.69% to 1.95% per month.

The average rates of profits (losses) of the representative large speculator (large hedger) in the foreign currency futures markets are lower than those in the commodity futures markets. The average rates of the representative large speculator's profits are equal to the average rates of the representative large hedger's losses in all the foreign currency futures markets. The average rates of the representative large speculator's profits and large hedger's losses in the Canadian dollar futures market are the lowest among all the foreign currency futures. In the Canadian dollar futures market the average rates of the representative large speculator's profits are from 0.56% to 0.74% per month and the average rates of the representative large hedger's losses are from 0.41% to 0.63% per month. In the other foreign currency futures markets, the average rates of the representative large speculator's profits are from 1.14% to 2.0% per month while the average rates of the representative large hedger's losses are from 1.32% to 1.76% per month.

The results of tests whether the representative large speculator has superior information are reported in Tables 2-23 through 2-33. The null hypothesis that the representative large speculator's profit is equal to the hypothetical speculator's profit on the average is rejected for every delivery month of wheat futures at a 1% significance level. This indicates that large speculators

have information which is superior to small traders' in the wheat futures market. Large speculators receive a risk premium from large hedgers but also they make money by having superior information.

We cannot reject the null hypothesis that the representative large speculator makes money as much as the hypothetical speculator makes on the average for any delivery month of corn, oats and soybeans futures. This indicates that large speculators have no superior information in these markets. Large speculators make profits by mainly risk-bearing in these markets.

The representative large speculator's profit is significantly greater than the hypothetical speculator' profit at the 5% level for January, March, and May futures of soybeans meal, and May and July futures of soybeans oil. The representative large speculator's profit is a combined reward for both risk-bearing and superior information in these 5 futures markets. For the other soybeans meal and soybeans oil futures large speculators' profits are considered to be largely rewards for risk-bearing.

The null hypothesis that the representative large speculator makes money as much as the hypothetical speculator makes cannot be rejected for any delivery month in the foreign currency futures markets. This indicates that large speculators have no advantageous information over small traders. Large speculators' profits are entirely

rewards for risk-bearing in the foreign currency futures markets.

Conclusions

In order to examine the existence of risk premia in the futures markets, we test whether the representative large hedger loses money in the futures markets. Large-sample tests show that the representative large hedger consistently loses money on the average in the futures markets. This indicates that large hedgers pay some risk premium in the futures markets. We also test whether the representative large speculator makes money in the futures markets. The empirical results shows that the representative large speculator consistently makes profit on the average. This is the reason why large speculators continue to remain in the futures markets. But we should be careful in interpreting this finding. There is nothing in our empirical results to indicate that an individual large speculator makes money in the futures markets. We may just conclude that futures contracts are being settled in favor of large speculators as a whole in the futures markets.

We perform another test in order to examine whether or not large speculators make a profit by having information superior to small traders'. It is shown that the large speculators are rewarded for risk-bearing as well as for

superior information in all wheat futures and a few soybeans meal and oil futures. In the other markets, the representative large speculator makes no more than the money which the hypothetical speculator makes. Hence it is believed that large speculators' profits are due to risk-bearing in these markets.

Table 2-1
Hedgers' Profits for Wheat Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	112	$-14832*10^{-6}$	$6344*10^{-6}$	-2.34
May	104	$-13749*10^{-6}$	$6096*10^{-6}$	-2.26
July	106	$-11731*10^{-6}$	$5696*10^{-6}$	-2.06
Sep.	105	$-15050*10^{-6}$	$5584*10^{-6}$	-2.70
Dec.	115	$-8948*10^{-6}$	$5279*10^{-6}$	-1.70

Table 2-2
Speculators' Profits for Wheat Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	112	$35637*10^{-6}$	$5548*10^{-6}$	6.42
May	104	$38233*10^{-6}$	$4980*10^{-6}$	7.68
July	106	$33376*10^{-6}$	$4810*10^{-6}$	6.94
Sep.	105	$36983*10^{-6}$	$4495*10^{-6}$	8.23
Dec.	115	$34660*10^{-6}$	$4247*10^{-6}$	8.16

Table 2-3
Hedgers' Profits for Corn Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	120	$-17493*10^{-6}$	$4285*10^{-6}$	-4.08
May	116	$-18210*10^{-6}$	$4235*10^{-6}$	-4.30
July	112	$-20239*10^{-6}$	$4575*10^{-6}$	-4.42
Sep.	110	$-19843*10^{-6}$	$4762*10^{-6}$	-4.17
Dec.	120	$-18642*10^{-6}$	$4386*10^{-6}$	-4.25

Table 2-4
Speculators' Profits for Corn Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	120	$19016*10^{-6}$	$4230*10^{-6}$	4.52
May	116	$21012*10^{-6}$	$4120*10^{-6}$	5.10
July	112	$21462*10^{-6}$	$4524*10^{-6}$	4.74
Sep.	110	$21826*10^{-6}$	$4682*10^{-6}$	4.66
Dec.	120	$19962*10^{-6}$	$4336*10^{-6}$	4.60

Table 2-5
Hedgers' Profits for Oats Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	90	$-11397*10^{-6}$	$6811*10^{-6}$	-1.67
May	90	$-7211*10^{-6}$	$6423*10^{-6}$	-1.12
July	91	$-7243*10^{-6}$	$6962*10^{-6}$	-1.04
Sep.	88	$-8955*10^{-6}$	$7189*10^{-6}$	-1.25
Dec.	91	$-11465*10^{-6}$	$6586*10^{-6}$	-1.74

Table 2-6
Speculators' Profits for Oats Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	87	$16073*10^{-6}$	$6899*10^{-6}$	2.33
May	87	$12162*10^{-6}$	$6514*10^{-6}$	1.87
July	89	$11163*10^{-6}$	$7055*10^{-6}$	1.58
Sep.	85	$14112*10^{-6}$	$7314*10^{-6}$	1.93
Dec.	88	$13544*10^{-6}$	$6740*10^{-6}$	2.10

Table 2-7
Hedgers' Profits for Soybeans Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	113	$-15487*10^{-6}$	$6517*10^{-6}$	-2.38
May	115	$-17089*10^{-6}$	$6272*10^{-6}$	-2.72
July	113	$-17198*10^{-6}$	$7245*10^{-6}$	-2.37
Sep.	99	$-19450*10^{-6}$	$6951*10^{-6}$	-2.80
Nov.	111	$-17868*10^{-6}$	$6072*10^{-6}$	-2.94

Table 2-8
Speculators' Profits for Soybeans Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	113	$26475*10^{-6}$	$6193*10^{-6}$	4.27
May	115	$27133*10^{-6}$	$5953*10^{-6}$	4.56
July	113	$27686*10^{-6}$	$6949*10^{-6}$	3.98
Sep.	99	$26861*10^{-6}$	$6694*10^{-6}$	4.01
Nov.	111	$20695*10^{-6}$	$5990*10^{-6}$	3.45

Table 2-9
Hedgers' Profits for Soybeans Meal Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^h:μ=0
March	106	$-7952*10^{-6}$	$6638*10^{-6}$	-1.20
May	107	$-7731*10^{-6}$	$6660*10^{-6}$	-1.16
July	112	$-10737*10^{-6}$	$7349*10^{-6}$	-1.46
Sep.	99	$-10602*10^{-6}$	$7253*10^{-6}$	-1.46
Oct.	102	$-9670*10^{-6}$	$6718*10^{-6}$	-1.44
Dec.	114	$-6891*10^{-6}$	$6171*10^{-6}$	-1.12

Table 2-10
Speculators' Profits for Soybeans Meal Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^s:θ=0
March	106	$25851*10^{-6}$	$6188*10^{-6}$	4.18
May.	107	$24537*10^{-6}$	$6264*10^{-6}$	3.92
July	112	$23374*10^{-6}$	$7080*10^{-6}$	3.30
Sep.	99	$23665*10^{-6}$	$6931*10^{-6}$	3.41
Dec.	114	$18117*10^{-6}$	$5966*10^{-6}$	3.04

Table 2-11
Hedgers' Profits for Soybeans Oil Futures
January 1976 - December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^h:μ=0
March	111	$-13506*10^{-6}$	$7542*10^{-6}$	-1.79
May	112	$-13563*10^{-6}$	$7144*10^{-6}$	-1.90
July	116	$-12570*10^{-6}$	$7295*10^{-6}$	-1.72
Sep.	99	$-15270*10^{-6}$	$8188*10^{-6}$	-1.86
Oct.	102	$-11571*10^{-6}$	$7600*10^{-6}$	-1.52
Dec.	115	$-10596*10^{-6}$	$6956*10^{-6}$	-1.52

Table 2-12
Speculators' Profits for Soybeans Oil Futures
January 1976 -December 1984 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^s:θ=0
March	111	$29349*10^{-6}$	$7121*10^{-6}$	4.12
May.	112	$31236*10^{-6}$	$6627*10^{-6}$	4.71
July	116	$29344*10^{-6}$	$6863*10^{-6}$	4.28
Sep.	99	$32096*10^{-6}$	$7676*10^{-6}$	4.18
Dec.	115	$23934*10^{-6}$	$6660*10^{-6}$	3.59

Table 2-13
Hedgers' Profits for Canadian Dollar Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	118	$-6327*10^{-6}$	$1306*10^{-6}$	-4.84
June	112	$-4090*10^{-6}$	$1230*10^{-6}$	-3.33
Sep.	113	$-5347*10^{-6}$	$1168*10^{-6}$	-4.58
Dec.	114	$-4629*10^{-6}$	$1196*10^{-6}$	-3.87

Table 6-14
Speculators' Profits for Canadian Dollar Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	118	$7420*10^{-6}$	$1256*10^{-6}$	5.91
June	112	$5803*10^{-6}$	$1166*10^{-6}$	4.98
Sep.	113	$6018*10^{-6}$	$1138*10^{-6}$	5.29
Dec.	114	$5621*10^{-6}$	$1158*10^{-6}$	4.85

Table 2-15
Hedgers' Profits for British Pound Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	98	$-18537*10^{-6}$	$2745*10^{-6}$	-6.75
June	87	$-18038*10^{-6}$	$2837*10^{-6}$	-6.34
Sep.	90	$-17926*10^{-6}$	$2981*10^{-6}$	-6.01
Dec.	100	$-19640*10^{-6}$	$2967*10^{-6}$	-6.62

Table 2-16
Speculators' Profits for British Pound Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	98	$18717*10^{-6}$	$2732*10^{-6}$	6.85
June	87	$18000*10^{-6}$	$2840*10^{-6}$	6.34
Sep.	90	$18072*10^{-6}$	$2971*10^{-6}$	6.14
Dec.	100	$20907*10^{-6}$	$2878*10^{-6}$	7.26

Table 2-17
Hedgers' Profits for Deutsche Mark Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	99	$-13181*10^{-6}$	$3521*10^{-6}$	-3.74
June	81	$-17359*10^{-6}$	$4044*10^{-6}$	-4.29
Sep.	93	$-13327*10^{-6}$	$3483*10^{-6}$	-3.83
Dec.	101	$-13545*10^{-6}$	$3438*10^{-6}$	-3.94

Table 2-18
Speculators' Profits for Deutsche Mark Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	99	$15020*10^{-6}$	$3445*10^{-6}$	4.36
June	81	$16640*10^{-6}$	$4408*10^{-6}$	3.77
Sep.	93	$13093*10^{-6}$	$3493*10^{-6}$	3.75
Dec.	101	$13834*10^{-6}$	$3427*10^{-6}$	4.04

Table 2-19
Hedgers' Profits for Japanese Yen Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^h:μ=0
March	87	$-17117*10^{-6}$	$3113*10^{-6}$	-5.50
June	77	$-19788*10^{-6}$	$3328*10^{-6}$	-5.95
Sep.	73	$-17311*10^{-6}$	$3105*10^{-6}$	-5.58
Dec.	90	$-14639*10^{-6}$	$4397*10^{-6}$	-3.33

Table 2-20
Speculators' Profits for Japanese Yen Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	z^s:θ=0
March	87	$17286*10^{-6}$	$3102*10^{-6}$	5.57
June	77	$16562*10^{-6}$	$3552*10^{-6}$	4.66
Sep.	73	$15100*10^{-6}$	$3261*10^{-6}$	4.63
Dec.	90	$14426*10^{-6}$	$4405*10^{-6}$	3.27

Table 2-21
Hedgers' Profits for Swiss Franc Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^h:\mu=0$
March	112	$-13843*10^{-6}$	$3488*10^{-6}$	-3.97
June	92	$-16163*10^{-6}$	$3482*10^{-6}$	-4.64
Sep.	96	$-14013*10^{-6}$	$3677*10^{-6}$	-3.81
Dec.	102	$-15166*10^{-6}$	$3630*10^{-6}$	-4.18

Table 2-22
Speculators' Profits for Swiss Franc Futures
January 1979 - September 1988 (excluding 1982)

Maturity	Number of Observation	Mean	Standard Error of Mean	$z^s:\theta=0$
March	112	$11442*10^{-6}$	$3565*10^{-6}$	3.21
June	92	$14897*10^{-6}$	$3543*10^{-6}$	4.20
Sep.	96	$11494*10^{-6}$	$3767*10^{-6}$	3.05
Dec.	102	$13132*10^{-6}$	$3708*10^{-6}$	3.54

Table 2-23
Tests of Speculators' Superior Information
for Wheat Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$20805*10^{-6}$	$8428*10^{-6}$	2.46
May	$24484*10^{-6}$	$7872*10^{-6}$	3.11
July	$21645*10^{-6}$	$7455*10^{-6}$	2.90
Sep.	$21933*10^{-6}$	$7168*10^{-6}$	3.05
Dec.	$25712*10^{-6}$	$6800*10^{-6}$	3.78

Table 2-24
Tests of Speculators' Superior Information
for Corn Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$1523*10^{-6}$	$6021*10^{-6}$	0.25
May	$2802*10^{-6}$	$5908*10^{-6}$	0.47
July	$1223*10^{-6}$	$6434*10^{-6}$	0.19
Sep.	$1983*10^{-6}$	$6678*10^{-6}$	0.29
Dec.	$1320*10^{-6}$	$6167*10^{-6}$	0.21

Table 2-25
Tests of Speculators' Superior Information
for Oats Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$4676*10^{-6}$	$9694*10^{-6}$	0.48
May	$4951*10^{-6}$	$9148*10^{-6}$	0.54
July	$3920*10^{-6}$	$9912*10^{-6}$	0.39
Sep.	$5157*10^{-6}$	$10256*10^{-6}$	0.50
Dec.	$2079*10^{-6}$	$9424*10^{-6}$	0.22

Table 2-26
Tests of Speculators' Superior Information
for Soybeans Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$10988*10^{-6}$	$8990*10^{-6}$	1.22
May	$10044*10^{-6}$	$8647*10^{-6}$	1.16
July	$10488*10^{-6}$	$10039*10^{-6}$	1.04
Sep.	$7411*10^{-6}$	$9650*10^{-6}$	0.76
Nov.	$2827*10^{-6}$	$8529*10^{-6}$	0.33

Table 2-27
Tests of Speculators' Superior Information
for Soybeans Meal Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$17899*10^{-6}$	$9075*10^{-6}$	1.97
May	$16806*10^{-6}$	$9143*10^{-6}$	1.83
July	$12637*10^{-6}$	$10205*10^{-6}$	1.23
Sep.	$13063*10^{-6}$	$10032*10^{-6}$	1.30
Dec.	$11226*10^{-6}$	$8583*10^{-6}$	1.30

Table 2-28
Tests of Speculators' Superior Information
for Soybeans Oil Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$15843*10^{-6}$	$10372*10^{-6}$	1.52
May	$17673*10^{-6}$	$9744*10^{-6}$	1.81
July	$16774*10^{-6}$	$10016*10^{-6}$	1.67
Sep.	$16826*10^{-6}$	$11223*10^{-6}$	1.49
Dec.	$13338*10^{-6}$	$9630*10^{-6}$	1.38

Table 2-29
Tests of Speculators' Superior Information
for Canadian Dollar Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$1093*10^{-6}$	$1812*10^{-6}$	0.60
June	$1713*10^{-6}$	$1695*10^{-6}$	1.01
Sep.	$671*10^{-6}$	$1631*10^{-6}$	0.41
Dec.	$992*10^{-6}$	$1665*10^{-6}$	0.59

Table 2-30
Tests of Speculators' Superior Information
for British Pound Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$180*10^{-6}$	$3872*10^{-6}$	0.04
June	$-38*10^{-6}$	$4014*10^{-6}$	-0.009
Sep.	$146*10^{-6}$	$4209*10^{-6}$	0.03
Dec.	$1267*10^{-6}$	$4134*10^{-6}$	0.30

Table 2-31
Tests of Speculators' Superior Information
for Deutsche Mark Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	$z:\theta-v=0$
March	$1839*10^{-6}$	$4926*10^{-6}$	0.37
June	$-719*10^{-6}$	$5982*10^{-6}$	-0.12
Sep.	$-234*10^{-6}$	$4933*10^{-6}$	-0.04
Dec.	$289*10^{-6}$	$3854*10^{-6}$	0.07

Table 2-32
Tests of Speculators' Superior Information
for Japanese Yen Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	$z:\theta-v=0$
March	$169*10^{-6}$	$4395*10^{-6}$	0.03
June	$-3226*10^{-6}$	$4868*10^{-6}$	-0.66
Sep.	$-2211*10^{-6}$	$4503*10^{-6}$	-0.49
Dec.	$-213*10^{-6}$	$6224*10^{-6}$	-0.03

Table 2-33
Tests of Speculators' Superior information
for Swiss Franc Futures

Maturity	Mean of Difference	Standard Error of Mean of Difference	z:θ-v=0
March	$-2401*10^{-6}$	$4988*10^{-6}$	-0.48
June	$-1266*10^{-6}$	$4968*10^{-6}$	-0.25
Sep.	$-2519*10^{-6}$	$5264*10^{-6}$	-0.47
Dec.	$-2034*10^{-6}$	$5189*10^{-6}$	-0.39

CHAPTER 3
RISK PREMIA AND PRICE VOLATILITY

Introduction

An underlying intuition of the normal backwardation theory is that the risk premium is related to the uncertainty of the future price. Danthine [1978] argues that the more uncertain the future price is, the more speculators receive rewards for their risk-bearing. Following Danthine's argument, we discuss the relationship between a risk premium hedgers pay for a futures contract and the volatility of the future futures price. Speculators ask more reward for risk-bearing and hedgers are willing to pay more risk premium as they expect that the futures price is more volatile, as long as the futures price is related to the cash price.
In other words, hedgers have to pay more risk premium to speculators for the compensation of risk-bearing of a futures contract as they expect the more volatile future futures price. The volatility of the futures price can be approximately measured by its variance. Therefore, we derive the relationship between the risk premium hedgers pay for a futures contact and the variance of the futures price and

test it empirically.

Theoretical Background

Participants in futures markets are (1) output hedgers, (2) input hedgers, and (3) speculators. We will look at the behavior of the representative agents from each group.

The representative agent is assumed to maximize his expected utility. Let the representative agent's utility function be strictly concave and characterized by constant absolute risk aversion. The utility function is given by

$$U(x) = -e^{-\alpha x}$$

where x is the agent's asset and α is the coefficient of constant absolute risk aversion. If x is a random variable with a normal distribution, maximizing expected utility E[U(x)] is equivalent to maximizing

$$E(x)-0.5\alpha V(x).$$ [5]

Suppose that a representative producer (output hedger) makes his production decision for time t at time t-1 when output price s_t is unknown. The producer can manage his risk by using the futures markets. At time t-1 when production decision is made, he sells at price $p_{t,t-1}$ quantity z_{t-1} of futures contracts which mature at time t. At time t he will sell his products y_t at spot price s_t and repurchase the

[5] See Hanoch and Levy [1969].

futures contracts z_{t-1} at price $p_{t,t}$. At maturity time t, $s_t = p_{t,t} + e_t$ where e_t represents basis risks.[6] Hence the producer's profit for time t is

$$\pi_t = s_t(y_t - z_{t-1}) - C(y_t) + p_{t,t-1}z_{t-1}$$

where $C(y_t)$ is the production cost. Let's assume that the production function is quadratic such that

$$C(y_t) = 0.5cy_t^2$$

The producer's expectation of profit for time t, formed at time t-1 is

$$E_{t-1}(\pi_t) = E_{t-1}(s_t)(y_t - z_{t-1}) - 0.5cy_t^2 + p_{t,t-1}z_{t-1}$$

The variance of the producer's profit for time t, formed at t-1 is

$$V_{t-1}(\pi_t) = V_{t-1}(s_t)(y_t - z_{t-1})^2$$

Thus, the producer's expected utility for time t, formed at time t-1 is given by

$$E(U) = E_{t-1}(\pi_t) - 0.5\alpha V_{t-1}(\pi_t) = E_{t-1}(s_t)(y_t - z_{t-1}) - 0.5cy_t^2 + p_{t,t-1}z_{t-1} - 0.5\alpha V_{t-1}(s_t)(y_t - z_{t-1})^2 \quad (3.1)$$

where α is the coefficient of the producer's risk aversion. The producer will maximize his expected utility given by (3.1). By maximizing expected utility (3.1) with respect to the outputs y_t and futures contracts z_{t-1}, we will get the

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[6] The producer can reduce the risks associated with price changes, but he cannot eliminate the basis risks such as quantity risk, quality risk, location risk, and expiration date risk. Here it is assumed that $E_{t-1}(e_t)=0$ and $p_{t,t}$ and e_t are statistically independent. Hence $E_{t-1}(s_t) = E_{t-1}(p_{t,t})$ and $V_{t-1}(s_t) = V_{t-1}(p_{t,t}) + V_{t-1}(e_t)$.

optimal outputs y_t and futures contracts z_{t-1}.

$$y_t = \frac{p_{t,t-1}}{c}$$

$$z_{t-1} = \frac{p_{t,t-1}}{c} + \frac{[p_{t,t-1}-E_{t-1}(s_t)]}{\alpha V_{t-1}(s_t)}$$

Multiplying the producer's supply of futures contracts by the number of producers (output hedgers), we get the aggregate supply of futures contracts by output hedgers.

$$Z_{t-1} = kz_{t-1}$$

where k represent the number of producers (output hedgers).

A representative producer (input hedger) also manages risks when the input price is uncertain. At time t-1 he obtains a revenue $R(x_t)$ from forward sales and buys at price $p_{t,t-1}$ quantity w_{t-1} of futures contracts which mature at time t. At time t he will purchase inputs required x_t at price s_t and sell at price $p_{t,t}$ quantity w_{t-1} of futures contracts which mature at time t. This input hedger's profit for time t is given by

$$\pi_t = R(x_t)-s_t(x_t-w_{t-1})-p_{t,t-1}w_{t-1}$$

where $R(x_t)$ is the revenue function with respect to inputs x_t. Let's assume that the marginal revenue with respect to inputs is

$$R'(x_t) = a-bx_t \text{ where } a > s_t.$$

The input hedger's expectation of profit for time t, formed at time t-1 is

$$E_{t-1}(\pi_t) = R(x_t) - E_{t-1}(s_t)(x_t - w_{t-1}) - p_{t,t-1}w_{t-1}$$

The variance of the input hedger's profit for time t, formed at time t-1 is

$$V_{t-1}(\pi_t) = V_{t-1}(s_t)(x_t - w_{t-1})^2$$

Therefore, his expected utility for time t, formed at time t-1 will be

(3.2) $$E_{t-1}(U) = E_{t-1}(\pi_t) - 0.5\beta V_{t-1}(\pi_t) =$$
$$R(x_t) - E_{t-1}(s_t)(x_t - w_{t-1}) - p_{t,t-1}w_{t-1} - 0.5\beta V_{t-1}(s_t)(x_t - w_{t-1})^2$$

where β is the coefficient of the input hedger's risk aversion. Maximizing the expected utility (3.2) with respect to inputs and futures contracts will yield the optimal inputs and futures contracts.

$$x_t = \frac{a - p_{t,t-1}}{b}$$

$$w_{t-1} = \frac{a - p_{t,t-1}}{b} + \frac{E_{t-1}(s_t) - p_{t,t-1}}{\beta V_{t-1}(s_t)}$$

Multiplying an individual input hedger's demand for futures contracts by the number of input hedgers, we get the aggregate demand for futures contracts by input hedgers.

$$W_{t-1} = mw_{t-1}$$

where m represents the number of input hedgers.

A representative speculator will buy futures contracts if he expects that the futures price at time t will be

greater than the futures price at time t-1, and sell futures contracts if he expects that futures price at time t will be less than the futures price at time t-1. The speculator's profit for time t is

$$\pi_t = (p_{t,t}-p_{t,t-1})f_{t-1}$$

where f_{t-1} is the speculator's net position of futures contracts. Positive f_{t-1} implies long position while negative f_{t-1} implies short position. The speculator's expected utility for time t, formed at time t-1 will be

$$(3.3) \quad E_{t-1}(U) = E_{t-1}(\pi_t)-0.5\delta V_{t-1}(\pi_t) =$$
$$[E_{t-1}(p_{t,t})-p_{t,t-1}]f_{t-1}-0.5\delta f_{t-1}^2 V_{t-1}(p_{t,t})$$

where δ is the coefficient of speculator's risk aversion. Maximizing expected utility (3.3) with respect to future contracts f_{t-1} will yield the optimal number of futures contracts.

$$f_{t-1} = \frac{[E_{t-1}(p_{t,t})-p_{t,t-1}]}{\delta V_{t-1}(p_{t,t})}$$

Multiplying an individual speculator's demand for futures contracts by the number of speculators, we get the aggregate demand for futures by speculators.

$$F_{t-1} = nf_{t-1}$$

where n represents the number of speculators.

The futures market is in equilibrium when the aggregate excess supply of futures contracts by hedgers equals the aggregate excess demand for futures contracts by speculators.

$$Z_{t-1}+W_{t-1} = F_{t-1}$$

The equilibrium price of futures contracts at time t-1 is

$$\overset{*}{p}_{t,t-1} = \frac{DE_{t-1}(p_{t,t})+ma/b}{D+k/c+m/b}$$

where $D = \frac{k}{\alpha[V_{t-1}(p_{t,t})+V_{t-1}(e_t)]} + \frac{m}{\beta[V_{t-1}(p_{t,t})+V_{t-1}(e_t)]} + \frac{n}{V_{t-1}(p_{t,t})}$

since $E(s_t)=E(p_{t,t})$ and $V_{t-1}(s_t)=V_{t-1}(p_{t,t})+V_{t-1}(e_t)$.

The difference between the expected future futures price $E_{t-1}(p_{t,t})$ and the equilibrium futures price $\overset{*}{p}_{t,t-1}$ at time t-1 is an ex ante risk premium.

$$E_{t-1}(r_t) = E_{t-1}(p_{t,t})-\overset{*}{p}_{t,t-1} = \frac{(k/c+m/b)E_{t-1}(p_{t,t})-ma/b}{D + k/c + m/b}$$

The ex ante risk premium is positively related to the expected variance of the future futures price at time t. Speculators ask more rewards for their risk-bearing as they expect that the future futures price is more volatile. So hedgers have to pay more risk premium as the future futures price is expected to be more volatile.

Hypotheses and Data

The hypothesis that risk premium hedgers pay is positively related to the variance of the futures price can be tested by setting up a regression equation.

$$r_t = \alpha + \beta\phi_t + \epsilon_t$$

where r_t is the ex post risk premium hedgers pay for a certain futures contract, ϕ_t is the ex post variance of the futures price. For instance, r_t is the ex post risk premium hedgers pay for March wheat futures contract, and ϕ_t is the ex post variance of its price at time t.

For empirical tests thirty futures within six commodities and twenty futures within five foreign currency futures are analyzed. The losses of the representative large hedger which were estimated in the previous chapter are used for the data of risk premia. The variance of the price of a futures contract is estimated with its daily prices at each month. We need normalization of the variances of the futures price in order to make the variance real and unitless. This enables us to compare the regression results across the commodities (and the foreign currencies). The sample variance of the futures price is divided by the square of the sample mean for normalization. The normalized sample variance of the futures price (coefficient of variation squared) is estimated as follows.

$$\phi_t = \frac{1}{\mu_t^2(n-1)} \sum_{j=1}^{n} (p_{h,t,j} - \mu_t)^2$$

$$= \frac{1}{(n-1)} \sum_{j=1}^{n} \left(\frac{p_{h,t,j}}{\mu_t} - 1 \right)^2$$

where $\mu_t = \frac{1}{n} \sum_{j=1}^{n} p_{h,t,j}$ and $n < 31$,

$p_{h,t,j}$ is the price of a futures contract on j date at t month, which matures at h month.

Regression Methods and Results

Since the data are time-series data, serial correlation of the error terms is possible. However, the Durbin-Watson (D-W) statistics indicate no serious problem due to the serial correlation of the error terms. The error terms in the equations are expected to be correlated across maturity and commodity (currency). Hence seemingly unrelated regression (SUR) procedures are used for estimation, because the SUR estimators are more efficient than the ordinary least squares (OLS) estimators when error terms are correlated across the equations. We might apply SUR to a group of equations across maturity within a commodity, or to a group of equations across commodity with the same maturity period. The former method is used for reporting the results because the errors terms are more correlated among different maturities within a commodity than among different commodities.

In order to apply SUR to a group of equations the data are merged by year and month. Merging the data seriously

reduces the number of observations available in oats, soybeans, and soybeans meal and Japanese yen futures. In these equations ordinary least squares (OLS) rather than the SUR are used in order to preserve degrees of freedom.

The regression results are reported in Tables 3-1 through 3-11. The estimate of the parameter β is positive and highly significant for most of the equations. The estimate of the parameter β is not significant in only seven out of fifty equations. These are the equations for March, May and July oats futures, March soybeans futures, and March, May, December soybeans meal futures. The estimate is more significant in the equations for foreign currency futures than in the equations for commodity futures.

The above findings indicate that the more volatile the price of a futures contract is the more hedgers lose money in this futures contract. That is, the risk premium hedgers pay for a futures contract is positively related to the variance of the futures price. For instance, The more volatile the price of March wheat futures is, the more hedgers pay risk premium for the futures contract.

To examine the possible effect of the volatility of the other commodity (currency) futures prices on the risk premium hedgers pay for a certain futures contract, we run multiple regressions as follows.

$$r_{t,i} = \alpha + \beta_1\phi_{t,1} + \beta_2\phi_{t,2} + \ldots + \beta_i\phi_{t,i} + \epsilon_t$$

where subscript i represents futures for commodity i

(currency i) which mature at the same month. Data used in these regressions are commodity (currency) futures which mature at March. The equations are estimated by OLS.

The regression results are reported Table 3-12 and 3-13. The estimate of the coefficient of own price variance is positive and significant in four out of six regression equations for March commodity futures and in four out of five regression equations for March foreign currency futures. The results indicate that the risk premium hedgers pay for a certain futures contract are in general positively related to the variance of its futures price. For the wheat and corn markets the coefficients of the variances of the other markets are not significant. However, for the oats market the coefficient of the variance of the corn futures is significant and positive whereas its own coefficient is negative. What this says is that hedgers in the wheat market do not take into account the variance in the oats market but hedgers in the oats market have to consider the variance in the corn market. A possible explanation for this is that the oats market is much smaller than the corn market.

Of more interest are the coefficients in the soybean complex. Here the variances of soybeans, bean oil, bean meal are all important explanatory variables in all the equations. The diagonal coefficients in Table 3-12 are substantially different from these reported in Tables 3-4 and 3-6. Furthermore, the sum of the coefficients of β_4, β_5,

and β_6 appears to be close to zero in all the three equations for SB, SL and SM in Table 3-12. This is a consequence of the fact that in the soybean complex producers do hedging by buying and selling contracts in beans, bean meal, and bean oil whenever there is a divergence between the prices of soybeans and the products.

Broadly speaking, a comparison of the multiple regression results in Table 3-12 with the simple regression results in Tables 3-1 through 3-6 indicates that the wheat and corn markets stand alone that there is some effect of the wheat market on the oats markets, and that the soybeans market and the markets for bean meal and bean oil are all interrelated. Thus, there is an omitted variable bias in the estimates from the simple regression presented in Tables 3-4 through 3-6.

As for Table 3-13, except for the equation for DM, the results indicate that the risk premium hedgers pay for a certain futures contract are positively related to the variance of that contract. The coefficients of the other equations are rather erratic maybe due to multicollinearity. The erratic results for the DM equation could also be attributable to multicollinearity. In the case of the currency markets, the variances in the different markets are often very interrelated.

It is also of interest to examine whether there is a relationship between the risk premium hedgers pay for a

certain futures contract and the variance of the other futures prices across maturity within a commodity. So we run multiple regressions.

$$r_{t,j} = \alpha + \beta_1 \phi_{t,1} + \beta_2 \phi_{t,2} + \ldots + \beta_i \phi_{t,j} + \epsilon_t$$

where subscript j represents the j th month maturity futures within a commodity (currency).

The data for wheat and Deutsche mark futures are used for the empirical tests. The regression results are reported in Table 3-14 and 3-15. The estimate of coefficient of own futures price variance is positive in seven equations out of the nine equations investigated and significant in three equations. The low significance of estimates may be due to multicollinearity. Only two estimates of the coefficient of the other futures prices are significantly positive. So we may conclude that the risk premium hedgers pay for a certain futures contract is more related to its own price variance than the variances of other maturity futures prices. For instance, the risk premium hedgers pay for May wheat futures is positively related to the variance of its price, but is not related to the variances of the prices of March, July, September, and December wheat futures.

Summary

This chapter develops the relationship between the volatility of the price of a futures contract and the risk

premium hedgers pay to speculators for the compensation of risk-bearing. It is postulated that the more volatile the futures price, the more risk premium hedgers pay for the futures contract. This hypothesis is empirically tested by regressing the ex post risk premium hedgers pay for a certain futures contract on the ex post variance of the futures price. The data on risk premia are obtained by calculating a representative large hedger' losses. The ex post variance of the futures price is estimated with its daily prices at each month. For the estimation of the regression equations, we use seemingly unrelated regression procedures since the error terms are correlated across the equations. The empirical results support the above hypothesis. That is, the risk premium hedgers pay for a futures contract is positively related to the variance of its price. We also test the possible effect of the volatility of other futures prices on the risk premium hedgers pay for a certain futures contract.

In the case of the wheat and corn markets, the volatility in the other futures prices is not important. In the case of the oats market, volatility in the corn market is relevant. In the case of soybeans. soybean oil and soybean meal, the volatility in all these markets is relevant in each of the three markets. These markets are strongly interrelated. In the case of each of the currency markets, the effect of the volatility in the other markets

cannot be clearly disentangled, because the volatility measures are intercorrelated.

Table 3-1
Regression Equations for Wheat Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$1648*10^{-6}$	19.732	0.25	4.33	2.02	7.95	0.082
	$(6522*10^{-6})$	(4.560)					
May	$-422*10^{-6}$	24.507	-0.60	5.26	2.00	13.01	0.128
	$(6999*10^{-6})$	(4.658)					
July	$-1057*10^{-6}$	24.673	-0.17	5.91	1.86	19.09	0.177
	$(6275*10^{-6})$	(4.173)					
Sep.	$-489*10^{-6}$	25.280	-0.08	5.98	2.01	18.29	0.171
	$(5942*10^{-6})$	(4.229)					
Dec.	$-1894*10^{-6}$	22.582	-0.30	5.54	1.79	12.27	0.121
	$(6407*10^{-6})$	(4.080)					

Table 3-2
Regression Equations for Corn Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$-899*10^{-6}$	41.906	-0.22	13.02	1.80	53.90	0.357
	$(4054*10^{-6})$	(3.219)					
May	$2611*10^{-6}$	40.429	0.64	12.56	1.73	44.71	0.316
	$(4308*10^{-6})$	(6.143)					
July	$-503*10^{-6}$	40.113	-0.12	9.80	1.91	32.73	0.252
	$(4187*10^{-6})$	(4.094)					
Sep.	$-2689*10^{-6}$	48.998	-0.61	11.79	1.96	52.73	0.352
	$(4422*10^{-6})$	(4.157)					
Dec.	$2811*10^{-6}$	40.048	0.67	12.81	1.93	52.84	0.353
	$(4214*10^{-6})$	(3.126)					

Note: Standard errors are shown in parentheses

Table 3-3
Regression Equations for Oats Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$6840*10^{-6}$	9.207	1.31	0.65	2.13	0.42	0.005
	$(5241*10^{-6})$	(14.256)					
May	$7049*10^{-6}$	0.872	1.05	0.06	2.02	0.003	0.000
	$(6723*10^{-6})$	(14.854)					
July	$-6164*10^{-6}$	20.304	-0.60	1.76	2.05	3.11	0.034
	$(10254*10^{-6})$	(11.513)					
Sep.	$-11361*10^{-6}$	28.993	-1.27	3.49	1.93	12.20	0.124
	$(8924*10^{-6})$	(8.302)					
Dec.	$-9013*10^{-6}$	31.241	-1.05	3.44	2.12	11.82	0.117
	$(8614*10^{-6})$	(9.087)					

Table 3-4
Regression Equations for Soybeans Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$1959*10^{-6}$	19.956	0.34	1.65	1.67	2.71	0.024
	$(5763*10^{-6})$	(12.129)					
May	$-1278*10^{-6}$	26.172	-0.26	2.39	1.82	5.70	0.048
	$(5001*10^{-6})$	(10.959)					
July	$918*10^{-6}$	21.355	0.14	2.11	1.91	4.44	0.039
	$(6531*10^{-6})$	(10.959)					
Sep.	$4752*10^{-6}$	19.478	0.54	2.64	2.26	6.97	0.067
	$(8750*10^{-6})$	(7.387)					
Nov.	$2633*10^{-6}$	21.409	0.34	3.05	2.19	9.29	0.079
	$(7698*10^{-6})$	(7.023)					

Table 3-5
Regression Equations for Soybeans Meal Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$-1093*10^{-6}$	11.560	-0.13	1.65	1.59	2.71	0.025
	$(8576*10^{-6})$	(7.025)					
May	$-2929*10^{-6}$	13.488	-0.33	1.76	1.64	3.11	0.029
	$(8949*10^{-6})$	(7.652)					
July	$-12535*10^{-6}$	23.485	-1.57	5.18	1.55	26.83	0.196
	$(8000*10^{-6})$	(4.534)					
Sep.	$-7774*10^{-6}$	21.326	-0.91	3.58	1.81	12.82	0.119
	$(8560*10^{-6})$	(5.955)					
Dec.	$800*10^{-6}$	7.802	0.10	1.23	1.81	1.50	0.013
	$(7914*10^{-6})$	(6.369)					

Table 3-6
Regression Equations for Soybeans Oil Futures

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$-1199*10^{-6}$	13.574	-0.14	4.92	1.71	7.71	0.079
	$(8586*10^{-6})$	(2.759)					
May	$-2530*10^{-6}$	14.189	-0.30	4.96	1.76	8.32	0.085
	$(8540*10^{-6})$	(2.860)					
July	$3727*10^{-6}$	9.928	0.41	2.63	1.74	1.54	0.017
	$(9040*10^{-6})$	(3.773)					
Sep.	$3229*10^{-6}$	11.314	0.37	4.16	1.71	8.61	0.087
	$(8818*10^{-6})$	(2.722)					
Dec.	$-2519*10^{-6}$	11.977	-0.30	4.85	1.82	5.79	0.061
	$(8533*10^{-6})$	(2.469)					

Table 3-7
Regression Equations for Canadian Dollar

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$2359*10^{-6}$	38.577	1.62	2.17	1.88	0.14	0.002
	$(1451*10^{-6})$	(17.806)					
June	$1923*10^{-6}$	63.618	1.27	3.07	1.94	2.60	0.031
	$(1510*10^{-6})$	(20.699)					
Sep.	$2038*10^{-6}$	61.051	1.38	3.25	1.82	2.49	0.030
	$(1475*10^{-6})$	(45.804)					
Dec.	$1809*10^{-6}$	60.698	1.16	3.31	1.93	2.47	0.030
	$(1561*10^{-6})$	(18.320)					

Table 3-8
Regression Equations for British Pound

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$7320*10^{-6}$	55.995	2.14	7.91	2.03	4.88	0.071
	$(3422*10^{-6})$	(7.079)					
June	$7839*10^{-6}$	56.018	2.45	8.24	2.10	11.30	0.150
	$(3194*10^{-6})$	(6.794)					
Sep.	$6926*10^{-6}$	61.876	1.89	7.17	2.09	9.12	0.120
	$(3655*10^{-6})$	(8.628)					
Dec.	$10048*10^{-6}$	54.943	2.58	6.01	2.19	4.39	0.064
	$(3892*10^{-6})$	(9.145)					

Table 3-9
Regression Equations for Deutsche Mark

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$5581*10^{-6}$	65.863	1.31	6.67	1.71	12.46	0.163
	$(4247*10^{-6})$	(9.875)					
June	$1690*10^{-6}$	74.750	0.51	12.89	1.76	35.33	0.356
	$(3320*10^{-6})$	(5.799)					
Sep.	$1046*10^{-6}$	78.440	0.31	10.74	1.65	43.23	0.403
	$(3402*10^{-6})$	(7.305)					
Dec.	$-529*10^{-6}$	77.550	-0.15	11.66	1.77	32.71	0.338
	$(3648*10^{-6})$	(6.648)					

Table 3-10
Regression Equations for Japanese Yen

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
Marc	$3511*10^{-6}$	79.832	1.14	7.41	2.02	54.85	0.395
	$(3078*10^{-6})$	(10.779)					
June	$3843*10^{-6}$	81.548	1.11	7.03	2.06	49.42	0.397
	$(3451*10^{-6})$	(11.600)					
Sep.	$3987*10^{-6}$	79.477	1.07	5.11	2.21	26.15	0.269
	$(3733*10^{-6})$	(15.543)					
Dec.	$927*10^{-6}$	76.140	0.18	4.31	2.19	18.55	0.176
	$(5174*10^{-6})$	(17.679)					

Table 3-11
Regression Equations for Swiss Franc

Maturity	Estimates / Test Statistics						
	α	β	t:α=0	t:β=0	DW	F	R^2
March	$1861*10^{-6}$	62.252	0.56	12.97	1.50	30.28	0.280
	$(3338*10^{-6})$	(4.799)					
June	$1216*10^{-6}$	62.034	0.37	15.38	1.79	32.21	0.292
	$(3316*10^{-6})$	(4.031)					
Sep.	$131*10^{-6}$	64.456	0.04	12.92	1.63	30.79	0.283
	$(3509*10^{-6})$	(4.989)					
Dec.	$-368*10^{-6}$	63.906	-0.10	12.34	1.90	30.10	0.278
	$(3667*10^{-6})$	(5.178)					

Table 3-12
Multiple Regression Equations for March Futures across Commodity

Commodity	Estimates / Test Statistic						
	β_1	β_2	β_3	β_4	β_5	β_6	R^2
Wheat	24.06	5.59	-0.21	-8.20	4.19	-5.62	0.107
	(2.87)	(0.47)	(-0.86)	(-0.32)	(0.45)	(-0.32)	
Corn	-7.19	50.96	0.32	-27.40	8.32	14.36	0.385
	(-1.31)	(6.52)	(0.04)	(-1.63)	(1.36)	(1.23)	
Oats	0.45	41.21	-15.15	-13.83	-3.65	13.56	0.140
	(0.05)	(3.32)	(-1.22)	(-0.52)	(-0.38)	(0.73)	
SB	-15.91	35.38	-9.96	-65.90	27.83	32.66	0.136
	(-1.62)	(2.53)	(-0.71)	(-2.19)	(2.54)	(1.57)	
SL	3.68	20.597	-47.94	-119.92	63.14	50.27	0.348
	(0.38)	(1.51)	(-3.52)	(-4.09)	(5.91)	(2.47)	
SM	-14.88	24.627	-10.88	-56.71	19.29	37.87	0.094
	(-1.51)	(1.76)	(-0.78)	(-1.88)	(1.76)	(1.91)	

Note: t-statistics are shown in parentheses.
SB = Soybeans
SL = Soybeans Oil
SM = Soybeans Meal

Table 3-13
Multiple Regression Equations for March Futures
across Currency

Currency	Estimates / Test Statistic					
	β_1	β_2	β_3	β_4	β_5	R^2
CD	79.27	-7.02	39.85	-7.32	-21.90	0.243
	(3.24)	(-0.71)	(3.53)	(-1.15)	(-2.67)	
BP	38.86	69.65	-15.79	-17.78	4.05	0.156
	(0.64)	(2.85)	(-0.57)	(-1.14)	(0.20)	
DM	-136.81	20.09	-1.81	12.63	23.40	0.157
	(-1.99)	(0.73)	(-0.06)	(0.71)	(1.01)	
JY	46.60	13.32	-62.19	93.15	12.33	0.463
	(0.88)	(0.63)	(-2.56)	(6.78)	(0.69)	
SF	-110.22	-19.56	-84.88	26.78	113.380	0.336
	(-1.54)	(-0.67)	(-2.57)	(1.43)	(4.73)	

Note : CD = Canadian Dollar
BP = British Pound
DM = Deutsche Mark
JY = Japanese Yen
SF = Swiss Franc

Table 3-14
Multiple Regression Equations for Wheat Futures across Maturity

Maturity	Estimates / Test Statistic					
	β_1	β_2	β_3	β_4	β_5	R^2
March	-28.62	16.43	18.00	34.71	-14.90	0.161
	(-1.01)	(0.51)	(0.63)	(1.02)	(-0.43)	
May	-27.68	40.69	18.78	30.32	-32.58	0.171
	(-0.90)	(1.16)	(0.60)	(0.81)	(-0.87)	
July	-24.48	1.06	70.55	20.76	-39.68	0.253
	(-0.90)	(0.03)	(2.57)	(0.63)	(-1.20)	
Sep.	-23.61	5.29	36.19	15.86	-5.33	0.206
	(-0.88)	(0.17)	(1.34)	(0.49)	(-0.16)	
Dec.	-14.24	4.85	18.83	42.32	-22.87	0.175
	(-0.50)	(1.50)	(0.65)	(1.22)	(-0.62)	

Table 3-15
Multiple Regression Equations for Deutsche Mark
Futures across Maturity

Maturity	Estimates / Test Statistic				
	β_1	β_2	β_3	β_4	R^2
March	66.41	-0.70	47.82	-23.32	0.206
	(1.54)	(-0.01)	(1.63)	(-0.42)	
June	-9.18	69.80	62.68	-16.99	0.436
	(-0.27)	(1.89)	(2.59)	(-0.39)	
Sep.	-3.33	-6.97	129.862	-10.17	0.414
	(-0.09)	(-0.17)	(5.06)	(-0.22)	
Dec.	-35.29	-24.00	61.04	100.55	0.421
	(-0.16)	(-0.60)	(2.34)	(2.16)	

CHAPTER 4
RETURNS TO SPECULATORS AND TIME-VARYING RISK-PREMIA: THE GARCH-M MODEL

Introduction

This chapter examines whether or not speculators receive time-varying risk premia. Like risk averse investors, risk averse large speculators who hold futures contracts ask more risk premia as the returns are expected to be volatile. That is, the larger the variance of the return from holding a futures contract is, the more they have to be compensated.

The measure of risks from holding risky assets has been an important research topic in financial economics. Traditionally, empirical studies in finance measure a risk from holding the risky asset by estimating the constant variance of the return. In these traditional studies the risk is invariant to time. Engle, Lilien, and Robins [1987] depart from the traditional measure of risk and use the Autoregressive Conditional Heteroskedasticity in Mean (ARCH-M) model which enables them to analyze time varying risks and risk premia. The ARCH-M is an extension of the

Autoregressive Conditional Heteroskedasticity (ARCH) model developed by Engle [1982].

In this study we use the Generalized ARCH-M model rather than the ARCH -M, since the GARCH process is a parsimonious model which describes data well. In the GARCH-M the current conditional variance depends on previous information and so is observable. So we can test whether the current conditional variance of the returns from holding the futures contract, which is time varying, determines the current mean of the returns.

A Short Survey on the ARCH Model

The ARCH model proposed by Engle [1982] is

$$y_t = a_0 y_{t-1} + \epsilon_t$$

$$\epsilon_t / \Omega_{t-1} \text{ --- } N(0, h_t)$$

$$h_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \ldots \alpha_p \epsilon_{t-p}^2$$

where Ω_{t-1} is a set of information available at time t-1, $\alpha_0 > 0$,and $\alpha_i \geq 0$, for i = 1 ... p.

The ARCH model is a generalization of a simple autoregressive model in that the conditional variance of the error term is allowed to depend on past history. So in the ARCH model the error term has time-varying conditional variance instead of the traditional constant variance. It is worth while to note some characteristics of the ARCH model.

First, the conditional distribution of the error term is normal, while the unconditional distribution is nonnormal and fat-tailed. Second, the error terms are serially uncorrelated, but not necessarily independent since they are related to another thorough the second moment.

For the estimation of the ARCH model, maximum likelihood method is used. The maximum likelihood estimator is nonlinear and more efficient than ordinary least squares. The relative efficiency of the maximum likelihood estimator depends on the value of α_1 in the ARCH process. When α_1 is close to unity, then the maximum likelihood estimator is highly efficient compared to the ordinary least squares.

The ARCH model has been extended in several ways. First, Bollerslev generalized the model by allowing the lagged conditional variances to appear in the current variance as follows.

$$h_t = \alpha_0 + \alpha_1\epsilon_{t-1}^2 + \ldots \alpha_p\epsilon_{t-p}^2 + \beta_1 h_{t-1} + \ldots \beta_p h_{t-q}$$

This model is called the generalized ARCH, or GARCH(p,q), model. The GARCH process can be written as an infinite order of the ARCH process. Hence the problem of over-parameterization in the ARCH model can be solved by using the GARCH(1,1) model.

Second, Engle, Lilien, and Robins [1987] further extended the ARCH model by allowing the conditional variance to affect the mean of the equation. This is the ARCH in mean model, or ARCH-M, which can be simply written as

$$y_t = \delta_0 + \delta_1 h_t + \epsilon_t$$

$$\epsilon_t / \Omega_{t-1} \text{ --- } N(0, h_t)$$

$$h_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \ldots \alpha_p \epsilon_{t-p}^2$$

The ARCH model has been useful in analyzing the time-series of prices in speculative markets. Current volatility of speculative prices depends on previous volatility, so that large changes tend to be followed by further large changes, and small changes tend to be followed by further small changes, (of either sign), as Mandelbrot [1963] observed. The ARCH model enables one to formalize the above phenomenon, since it allows the conditional variance to vary over time as a function of past squared error terms. Hence there have been a lot of empirical studies which analyze exchange rates, stock market returns, and futures prices using the ARCH model. For instance, Diebold and Nerlove [1985] use the ARCH model to analyze the volatility and the leptokurotosis of exchanges rate changes. Baillie and Bollerslev [1987] use the GARCH model to examine the time varying conditional heteroskedasticity of daily and weekly exchange rate changes. Maccurdy and Morgan [1987] use the GARCH-M model to test the evidence of time varying risk premia and volatility in foreign currency futures based on daily and weekly price data. [7]

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[7] In these study price change is the dependent variable.

Returns to Speculators: The GARCH-M Model

Risk averse investors require compensation for holding a risky asset. To the investors with portfolio choice between two assets, a risky asset and a riskless asset, the mean of the excess returns from holding the risky asset over the riskless asset is positively related to the variance of the excess returns and so is the risk premium. The same story holds for risk averse large speculators who invest in futures markets. Suppose the speculators are holding futures contracts (short or long). The speculators will ask more risk premia as they expect that holding futures contracts is more risky. Let the returns from holding the futures contract be y_t. Then the relationship between the expected value of return y_t from holding the futures contract, which is the ex ante risk premium, and the expected variance of return y_t can be approximately written as

(4.1) $\quad E_{t-1}(y_t) = \delta V_{t-1}(y_t) + b_0$

where δ is the coefficient of the speculator's constant risk aversion and b_0 is a remainder. The ex post return y_t is composed of ex ante risk premium $E_{t-1}(y_t)$ and the unforecastable return ϵ_t.

(4.2) $\quad y_t = E_{t-1}(y_t) + \epsilon_t$

$\quad E_{t-1}(\epsilon_t$/information available at time t-1) = 0

From equations (4.1) and (4.2) we have

(4.3) $\quad y_t = \delta V_{t-1}(y_t) + b_0 + \epsilon_t$

We use GARCH-M model to estimate equation (4.3).

(4.4) $y_t = b_0 + \delta h_t + \epsilon_t$

ϵ_t/Ω_{t-1} --- $N(0,h_t)$

$h_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 h_{t-1}$ [8]

where Ω_{t-1} is a set of information available at time t-1.

As Engle, Lilien, and Robins [1987] noted, the most useful information to economic agents is the set of previous surprises ϵ_t. Thus the conditional variance h_t is written as a function of a series of previous lagged squared errors. In this study the current conditional variance h_t is parameterized as a function of previous error squared ϵ_{t-1}^2 and conditional variance h_{t-1}, since the ARCH process of high order can be represented by the GARCH(1,1) process. Since the time-varying conditional variance is observable, we can examine whether it affects the mean of returns.

It is useful to include exogenous variable in deriving maximum likelihood estimation procedures as follows.

(4.5) $y_t = b_0 + b_1 x_t + \delta h_t + \epsilon_t$

The parameters can be combined into θ, where $\theta = \{b_0, b_1, \delta, \alpha_0, \alpha_1, \beta_1\}$, a k*1 column vector where k is the number of the parameters. The log likelihood function for (4.5) can be expressed as

(4.6) $L(\theta) = \sum_{t=1}^{T} L_t(\theta)$

---

[8] If $\alpha_0 > 0$, α_1, $\beta_1 > 0$, and $\alpha_1 + \beta_1 < 1$, then variance process is stationary. For details on the stationarity condition of the GARCH(p,q) process, see Bollerslev [1986].

where $L_t = \text{constant} - \frac{1}{2} \log h_t - \frac{1}{2} \frac{\epsilon_t^2}{h_t}$

The score vector at time t, denoted by S_t, is

$$S_t = \frac{\partial L_t}{\partial \theta} = \frac{1}{2h_t} \frac{\partial h_t}{\partial \theta} (-1 + \frac{\epsilon_t^2}{h_t} + 2\delta\epsilon_t) + \frac{x_t \epsilon_t}{h_t} \frac{\partial b_1}{\partial \theta}$$

Then the score vector, denoted by S, is

$$S = \frac{\partial L}{\partial \theta} = \Sigma \frac{\partial L_t}{\partial \theta}$$

The maximum likelihood estimates are obtained by solving the first order conditions given by

$$S = 0$$

Under regularity conditions set out in Crowder [1976], the information matrix at time t is given by

$$I_t = -E(\frac{\partial^2 L_t}{\partial \theta \partial \theta'}) = E(\frac{\partial L_t}{\partial \theta} \frac{\partial L_t}{\partial \theta'}) = E(S_t S_t')$$

The information matrix is

$$I = \Sigma E(S_t S_t')$$

The information matrix is not block diagonal between the parameters of the mean and the parameters of the variance in the GARCH-M model, unlike the simple ARCH model with no lagged dependent variable.

By adopting the Berndt, Hall, Hall, and Hausman [1974] approach, we obtain a solution to the maximization of this likelihood function.

$$\theta^{i+1} = \theta^i + \lambda^i (\Sigma S_t S_t')^{-1} \Sigma S_t$$

where θ^i denote the estimator after ith iteration and λ^i is a step length chosen to maximize the likelihood function in the given direction. The estimation procedure is as follows: Initially estimate the parameters in the mean equations by ordinary least squares and obtain the residuals. Using these residuals, we get efficient estimates of the parameters in the variance equation. Based on the efficient estimates of parameters in the variance equation, we can find efficient estimates of parameters in the mean equation, and obtain the residuals. Iterate again. [9]

Given the regularity conditions, the maximum likelihood estimates for θ are consistent and asymptotically normal with covariance matrix equal to the inverse of information matrix with limiting distribution.

$$T^{1/2}(\hat{\theta}-\theta) \xrightarrow{D} N(0,I^{-1})$$

In order to test the model specification against particular variables omitted from the model, we use a Lagrange multiplier (LM) test statistic. The LM test is

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[9] This study uses a computer program written by Kenneth Kroner. This program continue to iterate until a convergence criterion is reached. We may use as starting values estimates obtained from OLS. In the program the less numbers of parameters are, the easier the convergence is. So a effective way to estimation is: First estimate the variance equation with only endogenous variable, treating the mean equation fixed. If it converges, obtain the estimates of parameters in the variance equation. Using these estimates as starting values in the variance equation, estimate both the mean and variance equations together.

convenient since it requires estimates only under the null hypothesis. The LM test statistic under the null that certain parameters are zero is obtained by using formula suggested by Breush and Pagan [1980].

$$\Phi_{LM} = S_0 \; I_0^{-1} \; S_0$$

where S_0 is the score vector under the null hypothesis and I_0 is the information matrix evaluated at the null hypothesis. This LM statistic has an asymptotically chi-square distribution with p degrees of freedom where p is the number of restrictions when the null hypothesis is true. In case of the GARCH(1,1) process, the LM statistic under the null hypothesis that $\alpha_1 = \beta_1 = 0$ can be also obtained by TR_0^2 where T is the number of observations and R_0^2 is the squared multiple correlation coefficient from regressing ϵ_t^2 on ϵ_{t-1}^2 and h_{t-1}.

Results

The data used in this chapter are returns to a representative large speculator earned from wheat, corn, soybeans, Deutsche mark, and Japanese yen futures contracts which mature in March. Calculation of the returns is described in chapter 2.

The results of the GARCH-M model estimation are reported in table 4-1. As expected, the estimate of parameter δ is highly significant in every equation for

futures contract investigated here. Since δ is a coefficient of the representative large speculator's constant risk aversion, the estimate show that the representative large speculator is found to be risk averse. The estimates of the parameter α_1 are significant at the 5% level in two equations for wheat and corn futures, while they are significant at the 10% level in two equations for soybeans and Deutsche mark. The estimates of parameter β_1 are significant at the 10% level in the equation for Deutsche mark. The estimates of parameters α_1 and β_1 are all less than one, implying that the variance process in all equations is stationary and the unconditional variance is finite. It is found that there are strong ARCH-M effects for the three commodity equations and GARCH-M effects for Deutsche mark and Japanese yen. The above results indicate the representative large speculator receive time-varying risk premia from holding wheat, corn, soybeans, Deutsche mark, Japanese yen futures.

The significant GARCH-M effects in the case of currencies (and no such effects in the case of wheat, corn and soybeans) indicates that there is a long memory effect in the currency markets and not in the commodity markets. The currency markets are characterized by long swings as compared with the agricultural markets where the fluctuations are more related to the vagaries of the weather rather than to any long-lasting changes in economic

policies.

The Lagrange multiplier test enables one to evaluate the model specification against particular variables omitted from the mean or the variance in the equations. The diagnostic tests for GARCH-M model are reported in table 4-2. The diagnostic tests also confirm that either the ARCH-M or the GARCH-M model is appropriate for analyzing large speculator's time varying risk premia from holding the futures contracts.

Summary

This chapter has investigated whether the risk premia the large speculators receive are time-varying by using the GARCH-M model. There are strong ARCH-M effects for the three commodity equations and GARCH effects for the two equations for Deutsche mark and Japanese yen. The estimation results indicate that large speculators receive time-varying risk premia from holding these futures contract. Moreover, large speculators are found to be risk averse.

Table 4-1
GARCH-M Model Estimation

Equations	Estimates / Test statistics				
	δ	α_0	α_1	β_1	L
Wheat	4.982	0.0023	0.442	0.0046	136.00
	(3.53)	(1.77)	(3.68)	(0.14)	
Corn	9.363	0.0015	0.341	0.0010	163.89
	(3.47)	(2.27)	(2.23)	(0.002)	
Soybeans	5.000	0.0033	0.171	0.0010	120.77
	(2.78)	(1.35)	(1.70)	(0.001)	
DM	12.249	0.0002	0.126	0.4860	163.65
	(2.78)	(1.57)	(1.71)	(1.93)	
JY	17.841	0.0003	0.184	0.4880	178.96
	(3.43)	(0.97)	(1.60)	(1.22)	

Note: t-statistics are shown in parentheses.
L = log likelihood

Table 4-2
Diagnostic Tests for GARCH-M Model
(LM statistics)

Equations	Null hypothesis		
	$\delta = 0$	/	$\alpha_1 = \beta_1 = 0$
Wheat	1.37 (0.242)		19.74 (0.0001)
Corn	4.80 (0.028)		4.01 (0.104)
Soybeans	2.76 (0.097)		4.53 (0.104)
DM	4.15 (0.042)		14.43 (0.0007)
JY	1.63 (0.202)		17.78 (0.0001)

Note: p-values are shown in parentheses.

CHAPTER 5
SUMMARY AND CONCLUSIONS

This dissertation deals with three issues on the empirical evidence of risk premia in futures market. The first issue addresses to the question of whether or not hedgers pay a risk premium to speculators as a compensation for risk-sharing. The empirical tests are based on a sample of six commodity futures (wheat, corn, oats, soybeans, soybeans oil, and soybeans meal) and five foreign currency futures (Canadian dollar, British pound, Deutsche mark, Japanese yen, and Swiss franc). We adopt the general assumption that hedgers are net long or net short and so utilize the data on traders' commitments. Based on the large hedgers' and speculators' positions in futures trading, we estimate the returns to a representative large hedger and speculator. The test results show that the representative large hedger consistently loses money on the average in the futures markets. This implies that large hedgers as a whole pay some risk premium in the futures markets. On the other hand, the representative large speculator consistently makes money on the average, indicating that large speculators make money by risk-bearing or superior information. It is found

that large speculators make profits by risk bearing as well as superior information in a few futures contracts, but they make profits by risk-bearing rather than superior information in most of the futures contracts.

Second, we test whether large hedgers pay more risk premium as the futures price is more volatile. To do so, we regress the representative large hedger's ex post loss from a futures contract on the ex post variance of the futures price. The empirical evidence shows that in general the more volatile the futures price is, the more risk premium large hedgers as a whole pay for the futures contract. This result is also confirmed, except in a few cases as in the oats and DM markets, in the multiple regression equations where we introduce the volatility in the other markets as explanatory variables. In the case of the soybeans, bean oil, and bean meal markets are all important variables in explaining the risk premia in each of these markets. These three markets are highly interrelated. In the case of the currency markets, there appears some interrelationships but it is hard to disentangle these.

Finally, we test whether large speculators receive time varying risk premia using the framework of the GARCH-M model. The test results show that large speculators are risk averse and receive significant time varying risk premia from holding the futures contracts investigated here.

The empirical evidence of this study has an important

policy implication. The stabilization of the price of a futures contract will reduce the risk premium hedgers pay to speculators for the futures contract. But a certain level of price variation is needed in the futures market, because speculators will not hold the futures contract unless they are guaranteed a minimum level of return which would be otherwise obtained. Regulators set the limit of daily futures price changes and the margin requirements for futures contracts, which may affect the volatility of the futures prices. Given the important functions of risk transfer of futures markets, policy makers need to be aware of magnitudes of the risk premia and their relationship to measures of volatility. The derivation of these measures is the objective of this thesis.

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